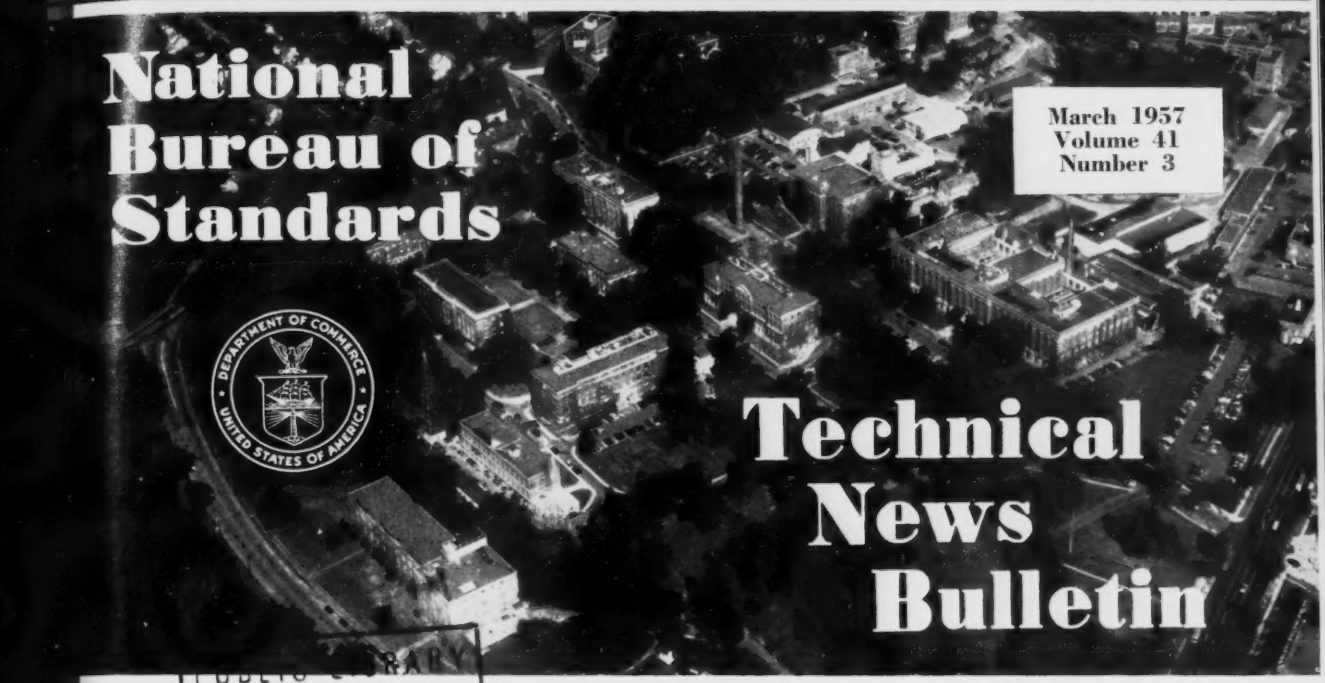
National Bureau of Standards

March 1957
Volume 41
Number 3



Technical News Bulletin

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MAR 20 1957
DETROIT

WEATHERING OF PORCELAIN ENAMELS

evaluated for architectural uses

THE NATIONAL BUREAU OF STANDARDS has recently completed a 15-year weather exposure test of porcelain-enameled steels. Since 1939, the Bureau has been conducting investigations of the weather resistance of such enamels by exposing a large number of samples to four climatic conditions, representative of different parts of the eastern United States. Results of the study should be useful to enamel manufacturers in further improving the weather resistance of porcelain enamels, and to architects and engineers in specifying the best weather-resistant compositions. The investigation was carried out by D. G. Moore and W. N. Harrison of the Bureau's enameled metals laboratory.

Large variations were found in the weather resistance of the various enamel types investigated. The enamels affected least by the exposure were those having high resistance to acid attack. The most resistant enamels retained more than 90 percent of their initial gloss and showed insignificant color changes (less than 1 NBS unit) whereas some of the enamels of poor acid resistance (which were not of a type recommended for outside exposure) changed from full gloss to a dull finish in 15 years.

Porcelain-enameled steel is finding increasing architectural use as an exterior finish for buildings. The material owes its popularity to good weather resistance, economy of construction, ease of cleaning, availability in a variety of colors, and a pleasing appearance. Exploratory installations of porcelain-enameled steel as the exterior finish of outdoor structures were made in Germany late in the 19th century. However, the greatest impetus to the use of the material for architectural applications has been in the United States. The application of porcelain enamels over a number of decades to architectural installations and advertising and street signs has provided a substantial backlog of experience. However, further information regarding the relative weather resistance of different types of enamel, and the correlation of laboratory test results with performance data, were needed to facilitate the selection of the most durable for architectural use.

For this study, 864 panels, 1 foot square, and an equal number of 4- by 6-inch laboratory specimens, were prepared by 16 cooperating manufacturers. Fourteen types of enamels were included. The base metal in each case was enameling iron. Exposure sites were selected at Washington, D. C., St. Louis, Mo., Lakeland, Fla., and Atlantic City, N. J.

A basic function of the porcelain enamel is to prevent corrosion of the base metal, hence all of the panels were inspected for evidence of corrosion of the steel base. After 15 years of exposure it was found that, where the initial coverage was complete on all parts of the panel, no corrosion occurred regardless of the type of enamel applied. However, on many panels the reverse side was protected with only a single ground-

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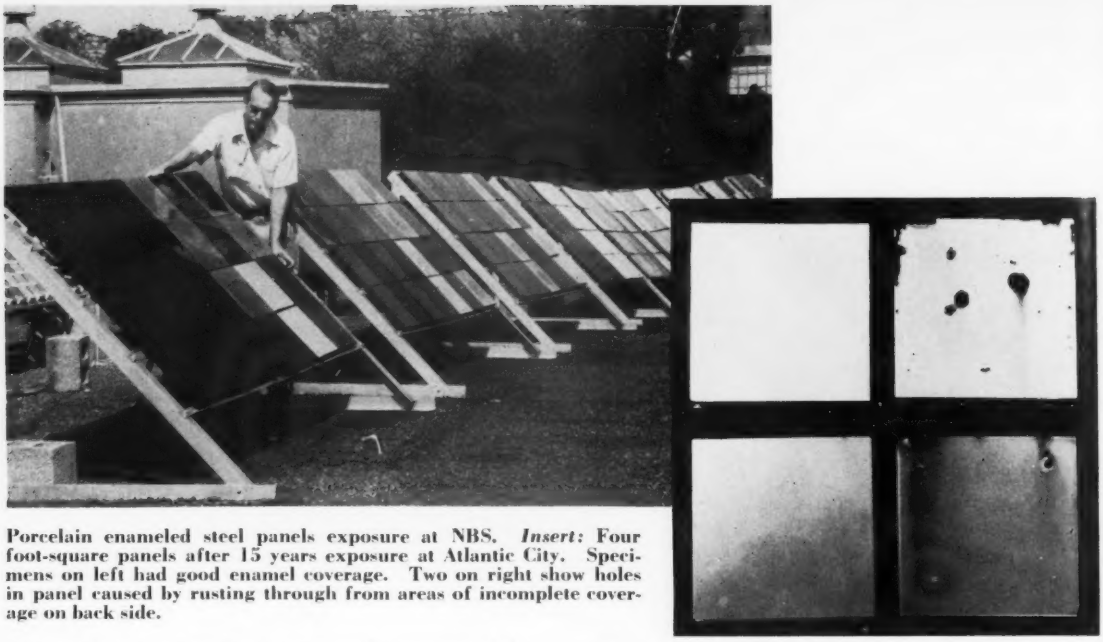


Porcelain enameled steel panels exposure at NBS. *Insert:* Four foot-square panels after 15 years exposure at Atlantic City. Specimens on left had good enamel coverage. Two on right show holes in panel caused by rusting through from areas of incomplete coverage on back side.

coat application. In these cases good coverage of the metal was not always achieved, especially where the specimens had rested on support points during firing. Corrosion started at these points of poor coverage and spalling of the enamel on the face side opposite the points occurred after the corrosion had progressed only part way through the steel. These spalled areas were more prevalent under the corrosive "salt-air" conditions of Atlantic City than at the other locations.

Porcelain enamels are noted for the ease with which they can be cleaned. Nevertheless, differences in cleanability were noted; the surfaces of high acid resistance were easier to clean after 15 years exposure than those of poor acid resistance. The semimat or satin-textured enamels showed about the same cleaning behavior as the glossy surfaces. On the other hand, none of the full-mat enamels could be cleaned satisfactorily even by a vigorous and prolonged scouring treatment.

The weather resistance of the enamel surface was evaluated by measuring the changes in the specular gloss and in the color. Such measurements showed that variations in climate had only a minor effect on the weathering behavior of most of the enamels. The same measurements showed that, on the average, the compositions that were highly resistant to attack by acid solutions were also resistant to the action of weathering. A few of the red enamels were found to deviate from this relationship: For example, conditions at the Lakeland site caused fairly large color changes in red enamels that had been given a good rating in the acid-resistance test that had been used.[1] A slow oxidation of the cadmium-selenium-sulfur pigment incorporated in the red enamels was believed to be responsible for the color change during exposure; hence, a laboratory test was devised in which specimens were subjected simultaneously to highly oxidizing conditions and to acid attack. The treatment consisted of 2½ hr. in a boiling 10-percent (by weight) solution of nitric acid. Results showed that when the weight loss of a laboratory specimen after this treatment was greater than 1 mg/cm^2, poor weather resistance was observed on its counterpart subjected to exposure; when weight loss was less than 1 mg/cm^2, the weather resistance was good.

The four selected sites all have fairly high annual rainfalls. Because weathering action is dependent on moisture, surface deterioration would be expected to proceed at a slower rate in a dry climate than at Washington, Lakeland, St. Louis, or Atlantic City. Likewise, in an area of extremely heavy rainfall, the weathering action would undoubtedly be accelerated.

Among the recomendations based upon the findings of this investigation, the one that may prove to be of greatest usefulness for specification purposes states that, for architectural installations where general appearance, absence of fading, and ease of cleaning are important, only those enamels having class A or class AA acid resistance by the standard citric acid spot test [1] should be used. In addition, for enamels containing the cadmium-selenium-sulfur pigment (red, orange, and yellow), only those compositions should be selected that will give a weight loss of less than 1.0 mg/cm^2 when subjected to a boiling solution of 10-percent nitric acid for 2½ hr.

For further technical information, see Fifteen-year exposure test of porcelain enamels, *by D. G. Moore and W. N. Harrison, a Building Materials and Structures Report of the National Bureau of Standards (in press). For earlier reports of the same investigation see J. Research NBS* **42,** *43 (1949) RP1949 and* **28,** *735 (1942) RP1476.*

[1] Test for acid resistance of porcelain enamels; Part 1–Flatwear. *Issued by the Porcelain Enamel Institute, 1145 19th Street, N.W., Washington 6, D. C.*

SMALL OIL-FREE BEARINGS

AT SUBZERO TEMPERATURES the oil in conventional small bearings congeals and interferes seriously with instrument performance. To help eliminate this difficulty, the Bureau has investigated several varieties of materials for possible application as oil-free bearings in clocks and similar mechanisms used aboard aircraft.[1] The study has revealed a number of materials that promise acceptable performance over a considerable part of the temperature range in which aircraft instruments must operate. Besides eliminating the difficulty due to congealing, oil-free bearings would also do away with the need for periodic cleaning and oiling during storage and service. H. S. White of the NBS rheology laboratory conducted the investigation, which was sponsored by the Bureau of Aeronautics, Department of the Navy.

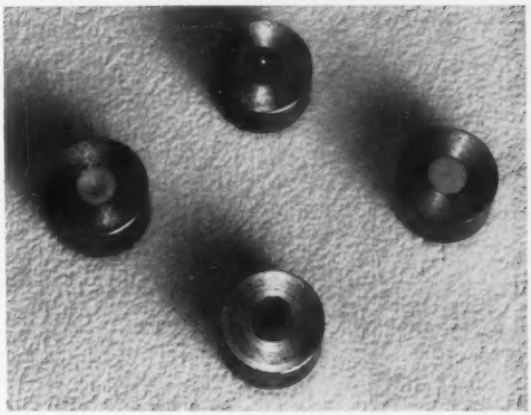
The increased viscosity and congealing of oils at subzero temperatures interfere with lubricated bearings by producing excessive friction. In some devices the added friction can be overcome by providing extra driving power. In the case of aircraft clocks and similar jeweled instruments, however, this is not feasible. The Bureau's study therefore concentrated on materials for oil-free bearings in timepiece mechanisms, and investigated them over the temperature range from $-60°$ to $+75°$C. The work consisted of measurement of the friction and wear characteristics and trials of the more promising materials in timepieces.

Bearing materials of 81 different compositions were investigated, some more intensively than others. One group of materials was made up of plastics such as polytetrafluoroethylene (PTFE), polytrifluorochloroethylene (PTFCE), and nylon. A larger group consisted of plastics with fillers—molybdenum powder, molybdenum disulfide, graphite, and glass, among others. Compositions with different proportions of the same filler were also included. Among the remaining materials were impregnated bronzes, impregnated carbon, bearing bronze, diamond, and sapphire. These materials were studied in combination with eight kinds of corrosion-resistant shaft materials.

Apparatus and Tests

The apparatus for the present study was chosen or designed to make simple comparative measurements of friction and wear characteristics of the bearing materials under conditions simulating those in service. Shafts ¼ in. in diameter were used for friction and wear measurements to give reasonable accuracy under various conditions of speed and load, and still be in the range of application of small oil-free bearings. Wear tests were made with ⅛-in.-diameter oscillating shafts as a compromise between ease of measuring the wear and smallness of the oscillating shafts in timepieces. For smaller shafts, timepieces were used for making comparative studies of the more promising materials.

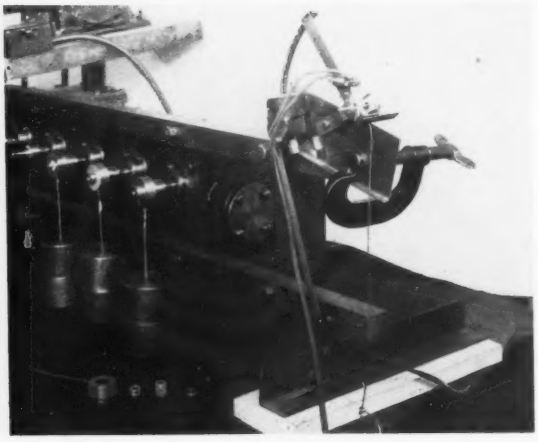
Frictional torque was determined from the displacement of a pendulum mounted outboard on a test bearing housing. Table 1 illustrates the frictional data obtained for typical materials under a variety of conditions. For measuring the wear of sleeve bearings on rotating journals, modified multiple-shaft speed-reducing units were used; desired speeds were produced by a motorized drive. Modified oscillating display motors were used in studying the wear of sleeve bearings on oscillating journals.



Specimens of four materials showing relative amounts of wear when used as endstones of oil-free thrust bearings. Mounted in ½-in.-diameter brass rings, the specimens are (counterclockwise, starting at top): Carbon-graphite-silver; PTFE; PTFCE; PTFCE+56% PTFE. Degree of wear is shown by depth of depression produced by hemispherical end (⅛-in. radius) of oscillating steel test pin under a thrust load of about 1,000 g. Test pin was turned back and forth through an angle of about 174° once every second for 60 days. PTFE=polytetrafluoroethylene; PTFCE=polytrifluorochloroethylene.

A special apparatus was designed for thrust-bearing wear tests with oscillating shafts. In this device, designated an "endstone-wear" testing machine, a motor-driven connecting rod turns a shaft back and forth through an angle of about 87°. This motion is doubled by gearing and then transmitted to four vertical shafts, each of which has a ⅛-in.-diameter hole and set-screw at each end for attaching steel test pins. An endstone specimen set in a 1,000-g weight supplies a load on each top pin; a specimen below each lower pin supports the 1,000-g weight plus the weight of the floating shaft and gear, a total thrust load of 1,240 g.

Oil-free bearing performance was studied in 18 timepieces also, including chronometers, clocks, and watches. This required minor modifications in some of the timepieces. Thus, the amplitude of motion of the balance wheels in the clocks and watches fitted with oil-free bearings was usually considerably less than the normal amplitude in oil-jeweled movements at ordinary temperatures. In most cases, therefore, heavier mainsprings were installed to increase the torque about 50 percent. However, in the chronometers the original mainsprings were able to supply the needed power.



Multiple-shaft speed-reducing units modified for study of wear with oil-free sleeve bearings on rotating journals. Several shafts can be seen at left, with weights suspended by wires from the bearing housings. One of the bearing assemblies is shown disassembled on table (lower left). Clamped at upper right is a modified oscillating display motor for studying wear with an oscillating shaft. A pair of test bearings are attached to a short shaft and loaded with a 2-lb weight (partly visible, lower right) suspended by wire.

Table 2 gives representative data for the performance of timepieces fitted with oil-free bearings. The sapphire pallet stones and the mainsprings and other metal-to-metal working parts in the watches and clocks were lubricated with MIL–O–11734 oil. The size of the heavier mainsprings left less free space in the mainspring barrels and allowed a correspondingly smaller number of turns in winding, so that they "ran down" in about 5 instead of 8 days. This may account for the stoppage of one clock on the fifth day, as its mainspring was nearly unwound when it stopped. The range of temperature ($-60°$ to $+75°$ C) is beyond that ordinarily compensated for in timepieces, and this may account for some of the variation in rate with temperature for chronometer 13370 and clock 33413E. A laboratory oven and a commercial subzero chest were used for maintaining the high and the low temperatures that were thermostatically controlled. Considering the wide range of temperature, the rates for the other timepieces were relatively unaffected.

Discussion

Wear-test data and experience with polytetrafluoroethylene (PTFE) in an aircraft clock and in a chronometer indicate that this material (without fillers) is not suitable for general use as a bearing material. However, at low surface speeds and low unit pressures its wear resistance may be adequate for special applications. The increase in friction at temperatures below $-20°$ C reduces its usefulness at low temperatures.

The high friction of polytrifluorochloroethylene (PTFCE) at ordinary temperatures, and the rates of wear obtained with it do not recommend its use as an oil-free bearing material. Nevertheless, the way in which its friction decreases with decrease in temperature makes it useful for special low-speed applications.

PTFCE with a 10- to 60-percent filler of PTFE is one of the most promising oil-free bearing materials developed during the investigation. A patent covering this type of material has been applied for by the U. S. Government. This material has some of the hardness characteristics of PTFCE, the frictional characteristics of PTFE, and a wear resistance much greater than either of these plastics alone. Unfortunately, the fact that its frictional characteristics are similar to those of PTFE detracts from its usefulness at temperatures below $-20°$ C.

Another promising material is PTFE containing molybdenum metal powder as a filler. This composition has good frictional characteristics and exceptionally good wear resistance under certain conditions. A patent (No. 2,715,617) on this type of material has been assigned to the Government.

The addition of a filler to PTFE usually decreases the wear greatly, but the filler of silver precipitated flowers is an exception. Microscopic examination suggests that although the silver particles are much less than 1 μ (0.0001 cm) in size, they have a strong tendency to form conglomerations larger than 5 μ. Because of the conglomerations, it is possible that PTFE does not surround and bind the individual silver particles; and the breakup of the conglomerations may cause the high wear and friction. Particle sizes from 0.5 to 5 μ appear to be especially suitable for fillers in PTFE compositions for small oil-free bearings. Molybdenum metal power is readily available in these particle-sizes.

In general, the metal-impregnated carbon materials showed good friction and wear characteristics. Their low coefficients of thermal expansion are an additional advantage and their good electrical conductivity may be useful in some applications. A lack of homogeneity in the samples used is indicated by the spread of data obtained with this material on the endstone-wear testing machine. This result, and the relative coarseness of the structure, discourage the use of such materials for bearings of less than $\frac{1}{16}$-in. bore.

No material proved as satisfactory as sapphire for pallet stones in timepieces. The results indicate that sapphire would be suitable for the material of unlubricated endstones when the load is relatively light, especially in timepieces normally operating in an upright position. Unlubricated sapphire hole bearings (jewels) caused rapid wear or rusting of the conventional balance-staff pivots in timepieces.

The porous bronzes, examined under the stereomicroscope, revealed pores and sections of solid bronze that were occasionally much larger than the diameters of common balance-staff journals. This would make impregnated porous bronze impractical for such journals. Also, for larger journals, the friction and wear data for porous bronze impregnated with PTFE and with molybdenum disulfide discourage its use for an oil-free bearing under the conditions investigated.

The characteristics exhibited by boron carbide without lubrication appear to make it unsuitable for use as pallet stones or as journal-bearing material. Also, under the conditions studied, ordinary brass and bear-

ing bronze appeared unsuitable for this application without lubrication.

Results of an investigation of fused coatings of PTFCE plus graphite and of PTFE one-coat enamel were not promising. Because of the thickness of the coatings ordinarily used and the difficulty in making a uniform coating with a good bond on small parts, the use of coatings does not seem practical for journals or bearings less than 1/16 in. in diameter.[2]

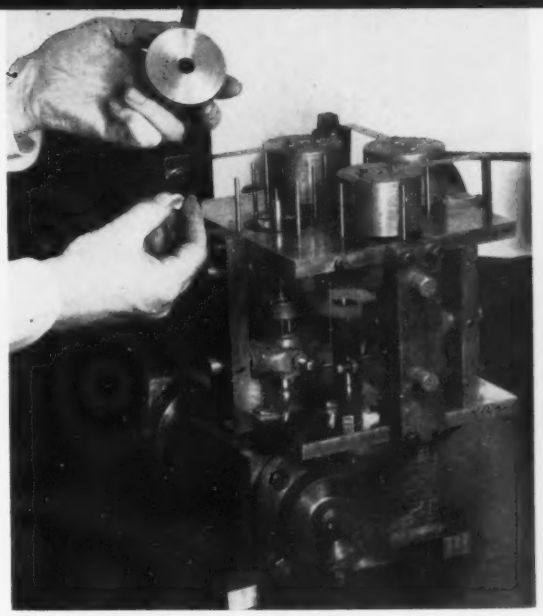
[1] *For further technical details, see* Small oil-free bearings, by H. S. White, *J. Research NBS* **57**, *185 (1956) RP2709.*

[2] *Work at the Naval Research Laboratory indicates that PTFE coatings may be useful for some purposes. See* Frictional behavior of polyethylene, polytetrafluoroethylene, and halogenated derivatives, *by R. C. Bowers, W. C. Clinton, and W. A. Zisman, Lubrication Eng.* **9**, *204 (1953).*

TABLE 1. *Typical data obtained with hardened stainless-steel shaft at 3, 15, and 300 rpm, showing effects of run-in and ambient temperature on friction*

[For timepiece bearings the friction at 3 rpm (corresponding to 0.2 ft/min) is considered more significant than data at higher speeds. Also, the friction after run-in is considered more significant than the initial friction. PTFE=polytetrafluoroethylene; PTFCE=polytrifluorochloroethylene; C=diametral clearance]

Sample	Bore condition	Load	Ambient temperature	Coefficient of friction		
		g	°C	*3 rpm*	*15 rpm*	*300 rpm*
PTFCE+30% PTFE, fused at 500° F.	Reamed, C=0.008 in.	2,200	25	0.13	0.18	0.23
	After 7 hr at 300 rpm.		25	.11	.13	.24
	After 7 hr at 3 rpm		25	.15	-----	-----
	After standing overnight.		25	.13	-----	-----
			0	.13	-----	-----
			−20	.14	-----	-----
			−40	.19	-----	-----
			−50	.24	.29	.33
	After speed range at −50° C.		−50	.27	-----	-----
			−60	.31	-----	-----
	After 6 hr at 3 rpm at −60° C.		−60	.33	-----	-----
	After standing overnight.		25	.13	.14	.23
PTFE+65% (20% vol) molybdenum powder (0.5 to 5 μ).	Reamed, C=0.098 in.	2,200	25	.08	.13	.19
	After 8 hr at 300 rpm.		25	.21	.23	.25
	After 8 hr at 3 rpm		25	.26	-----	-----
	After standing overnight.		25	.18	-----	-----
			0	.18	-----	-----
			−20	.18	-----	-----
			−40	.20	-----	-----
			−50	.21	.22	.25
	After speed range at −50° C.		−50	.22	-----	-----
			−60	.22	-----	-----
	After 6 hr at 3 rpm at −60° C.		−60	.23	-----	-----
	After standing overnight.		25	.19	.19	.20
Carbon+graphite +silver.	Reamed and burnished, C=0.002 in.	2,200	25	.16	.18	.23
	After 2 hr at 300 rpm.		25	.25	.25	.27
	After 4 more hr at 300 rpm.		25	.22	.24	.27
			0	.23	-----	-----
			−20	.24	-----	-----
			−40	.26	-----	-----
			−50	.27	.27	.27
	After speed range at −50° C.		−50	.25	-----	-----
			−60	.26	-----	-----
	After 5 hr at 3 rpm at −60° C.		−60	.23	-----	-----
	After standing overnight.		25	.22	.23	.26



Endstone-wear testing machine designed for studying the wear produced by oscillating shafts on oil-free thrust bearings. Motor drive (not visible) and gear train cause each of four vertical shafts to turn back and forth through an angle of about 174°. Shafts have steel test pins at each end in contact with specimen endstones above and below. A 1,000-g weight, fitted above upper endstone, loads both thrust bearings of each shaft. In operator's left hand is one of the weights, removed from position to show the test pin projecting above upper horizontal plate. Operator's right hand holds specimen oil-free endstone mounted in metal ring which fits into depression in bottom of weight.

TABLE 2. *Timepiece performance at various ambient temperatures, with oil-free bearings, except for MIL-O-11734 oil on pallet stones, mainsprings, and other metal-to-metal parts*

Timepiece	Oil-free bearings		Gain (+) or loss (−) in 24 hr		
	Sample	Number	−60° C	+25° C	+75° C
			sec	*sec*	*sec*
Ship chronometer No. 6512, dial up, wound daily.	PTFE	[a] 10	+17	−1	−40
			+10	−½	−20
			+7	0	−14
			+8	0	−13
			+10	−½	−9
Ship chronometer No. 13370, dial up, wound daily.	PTFE +Mo.	[a] 10	−118	+½	+38
			−148	0	+40
			−102	−½	+41
			−112	−1	+47
			−116	−½	+43
Navigation watch No. 995-41, 24-00 up, wound daily.	PTFCE +PTFE	19	−7	+53	+78
			−7	+53	+69
			+51	+55	+60
			+37	+49	+86
			+27	+59	+85
Navigation watch No. 964-42, dial up, wound daily.	PTFE +Mo.	19	−79	+1	−10
			−33	−3	+20
			−5	−10	+26
			−2	−16	+17
			−31	−4	0
Ship clock No. 33413E, 12:00 up, 1 winding.	PTFE+Cu	9	−311	+123	−143
			−334	+2	−35
			−344	−12	−101
			−330	−17	−200
			−354	−23	−200
Ship clock No. 45121E, 12:00 up, 1 winding.	Carbon+graphite +silver.	9	+9	+52	+10
			+7	+31	+10
			+2	−3	+6
			+12	−15	0
			Stopped	−12	+2

[a] Including 1 diamond and 1 sapphire endstone, unlubricated.

PUNCHED-CARD TRANSCRIBER FOR AUTOMATIC COMPUTERS

A PUNCHED-CARD TRANSCRIBER developed by the Bureau makes possible more rapid feeding of data into an automatic computer. The device is designed to convert numbers and instructions recorded on punched cards into a binary serial code. In this form information is suitable for direct rapid input into the computer or temporary storage as a magnetic recording. The system is extremely fast—about 150 times faster than the present paper tape inscriber—and can handle up to 600 cards per minute. Intended primarily for use with the Bureau's high speed electronic computer, SEAC,[1] the transcriber was developed by M. Stein of the Bureau's data processing systems laboratory.

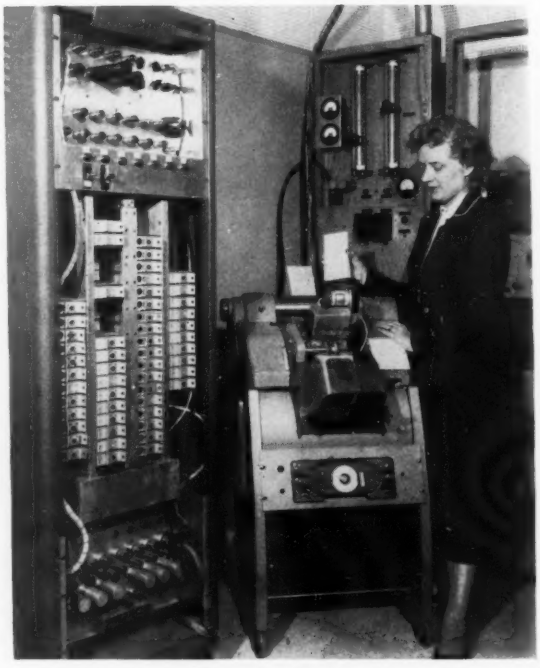
The transcriber can be utilized either as a means of preparing and feeding coded mathematical routines to the computer or for recording information on magnetic wire from cards that are already in existing files. In the preparation of routines, the use of punched cards offers an important advantage over perforated paper tapes. The cards provide a flexible means of modifying routines by simple insertions and removals. Previously, alterations in programing required remaking an entire punched paper tape.

When information appears on a punched card, it is in the form of 1 or 2 holes per column, representing numeric and alphabetic characters, respectively. The transcriber serially scans the 80 columns on each card with photoelectric cells and converts the data, one column at a time, into a 4- or 6-digit binary code at a rate ordinarly of 200 cards per minute. This speed is dictated by the maximum pulse density allowed on the associated magnetic wire system. A simple mechanical conversion, however, can change the basic speed to 400 or 600 cards per minute. The card reading mechanism is adapted from a commercial counting device.

In SEAC the hexadecimal counting system requires a 4-bit (binary digit) code accommodating 10 decimal digits and 6 letters, A through F. The 6-bit feature is incorporated into the transcriber to provide for coding the remainder of the alphabet in special data processing problems. One to six SEAC words can be punched on each card for use with the 4-bit code. The 6-bit code permits the use of 8 words per card.

The circuitry is built up in two modes. One group is constructed with plug-in transformers and diode clusters similar to those in SEAC. The other group utilizes diode gated amplifier and delay line packages[2] identical with those in DYSEAC.[3]

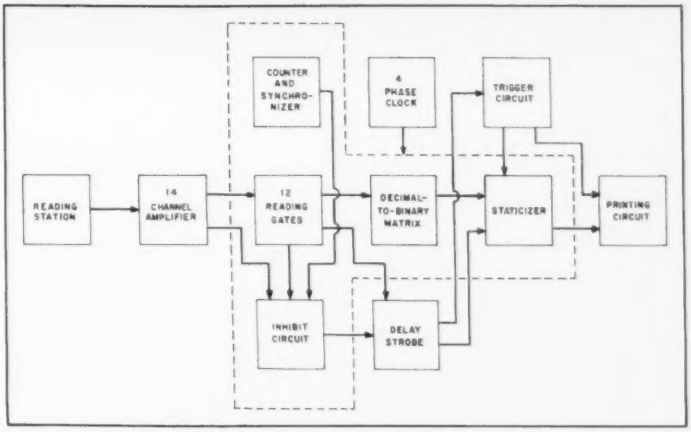
The transcriber consists of two physically separate units. Most of the electronic circuitry is contained in the main chassis, whereas the photoelectric reading station is mounted on the counting device. It contains the photocells, light source, and necessary circuitry for converting the basic hole patterns into voltages in 14 different information channels. Twelve of the channels are for direct information transmittal and the remaining two are for control purposes. Pulses coming from the 12 photocell information channels are fed into a gating matrix whose output is a 6-bit binary code. For hexadecimal operation two of the positions are muted to give a 4-bit output.



Punched-card transcriber developed for more rapid feeding of data into an automatic computer. Cards are fed into reading device (center) where they are handled at the rate of 200 to 600 per minute. Electronic circuitry in cabinet (left) converts data into form suitable for input into a computer and records it on magnetic wire.

The remainder of the electronic circuitry utilizes the above signals to produce a parallel binary code which is stored one column at a time in a six-position staticizer. Each group of six pulses is then serialized and made available to the print circuit before the next card column is read.

The major portion of the circuitry is used to achieve the various complex timing functions which are inherent in a device of this type and to prevent misinterpretation of alphabetic data. One provision prevents false read-outs during the intercard gap because at this time all the information channels are energized. Another provision compensates for card skew during the



Block diagram of the punched-card transcriber. The circuitry enclosed by dotted lines was constructed with diode gated amplifiers and delay line packages identical to those in DYSEAC.

reading process, and hole misalinement in the card itself.

All timing circuits are keyed to a strobe pulse which is initiated by the leading edge of each punched column. This means that card flow need not be synchronous nor data flow continuous. The resultant output information is therefore available whenever data fields are being read, and there is no output at any other time.

Flexibility of operation is further enhanced by a self-inhibiting feature which allows entire fields of information to be ignored by the sensing circuits. Thus it is possible to punch descriptive information as well as computer data on the same card and only the desired data will be transcribed.

Prior to being put into operation, acceptance tests were performed on the transcriber in which ¼ million hexadecimal characters were converted without error into their binary equivalent. These figures, representing 20,000 SEAC words, were recorded under varying adverse conditions more severe than would be encountered in normal operation. To date, most of the information transcribed has been matrix data from existing card files.

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[1] SEAC, the National Bureau of Standards Eastern Automatic Computer, *NBS Tech. News Bul.* **34,** *121 (September 1950).*

[2] Circuitry "packages" for electronic computers, *NBS Tech. News Bul.* **37,** *36 (March 1953).*

[3] DYSEAC, the new NBS electronic computer, *NBS Tech. News Bul.* **38,** *134 (September 1954).*

For additional information on the NBS computer program see Computer development (SEAC and DYSEAC) at the National Bureau of Standards (*C551*). *Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Price, $2.00.*

URSI to Meet in Boulder

FIVE hundred scientist-delegates are expected to attend the triennial meeting of the 12th general assembly of the International Scientific Radio Union in Boulder, Colorado, Aug. 22 through Sept. 5, 1957.

Invited to the United States by the U. S. A. National Committee of the Union, URSI will have as local hosts the Boulder laboratories of the National Bureau of Standards, the University of Colorado, the High Altitude Observatory, and the city of Boulder. J. H. Dellinger, former Chief of the NBS Central Radio Propagation Laboratory, is chairman of the general arrangements committee. In charge of local arrangements is Kenneth A. Norton, Chief of the NBS Radio Propagation Engineering Division.

Popularly referred to as URSI from the initials of the French title, Union Radio Scientifique Internationale, the organization will bring together scientists from at least 25 member countries, including the United States, to pool information on present radio studies and to map plans for future international research programs. Scientists who will attend are being selected by the URSI national committees of their countries.

Established in 1919 by a group of far-seeing scientists assembled in France, URSI will be meeting in the United States for the second time within 30 years. The second general assembly was held in Washington, D. C. in 1927. Other hosts have been Belgium, Denmark (twice), England, Italy, France, Sweden, Switzerland, Australia, and the Netherlands. Through its vital role in fostering international collaboration, URSI has been responsible for significant achievements derived not only from general assembly discussions but from the permanent URSI Commissions that conduct continuous studies in the major fields of radio research.

CURRENT ADVANCES in fire protection technology at the National Bureau of Standards may provide a means to reduce further the loss of lives and property due to accidental fires. Many of the Bureau's recommendations have already been incorporated in underwriters' and municipal building codes, with consequent savings in life and prevention of property damage. However, there is a continuing need for technical information on the fire hazard properties of new building materials and structural assemblies. A better knowledge of the basic mechanisms of ignition, spread, and extinguishment of fires is essential for effective fire prevention and control.

Much of the Bureau's activity in these areas results in technical papers and reports that make data available to science and industry. Such information is frequently used as the basis of equipment design, specifications, and building codes.

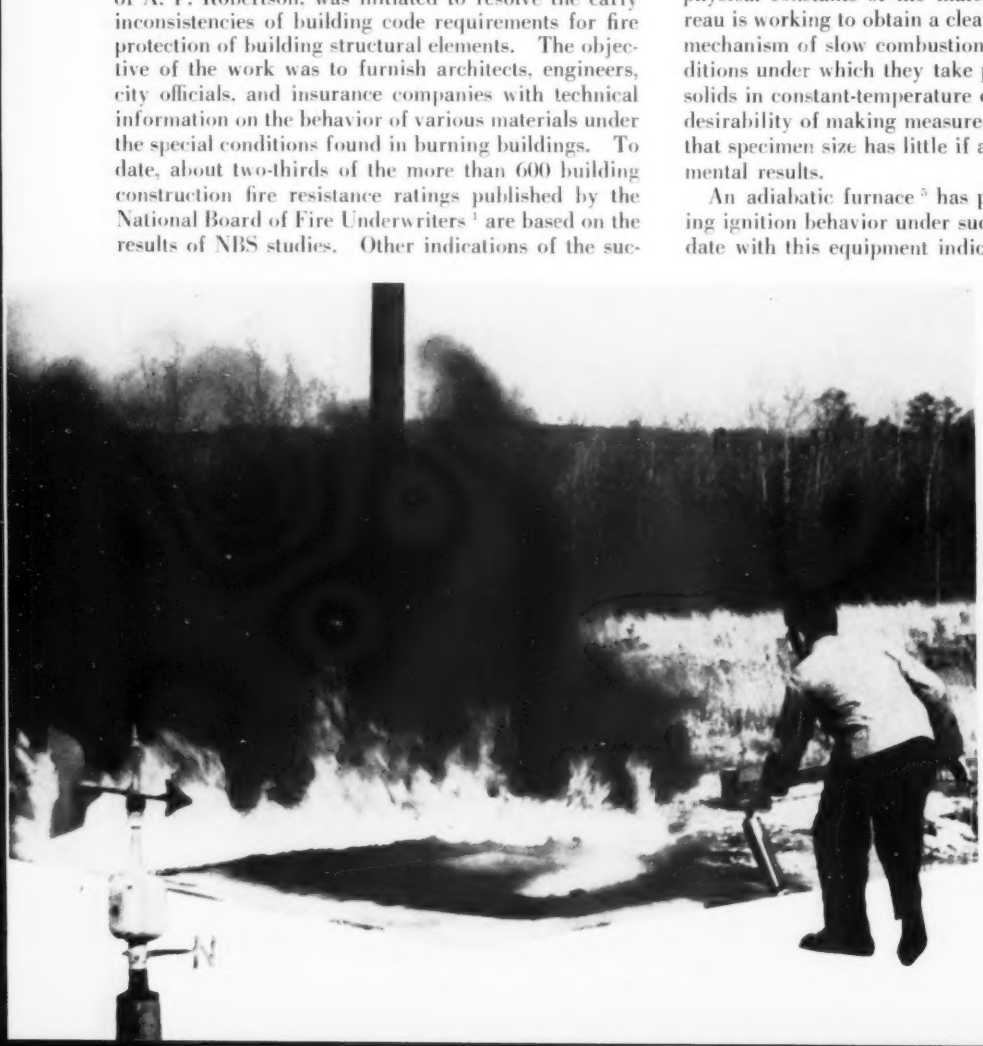
To provide basic information on ignition phenomena and fire resistance of materials, on flame detection and extinguishment, and on fire growth and spread, the Bureau has, since 1914, carried on an extensive program of research and development in the field of fire protection. This program, now under the direction of A. F. Robertson, was initiated to resolve the early inconsistencies of building code requirements for fire protection of building structural elements. The objective of the work was to furnish architects, engineers, city officials, and insurance companies with technical information on the behavior of various materials under the special conditions found in burning buildings. To date, about two-thirds of the more than 600 building construction fire resistance ratings published by the National Board of Fire Underwriters [1] are based on the results of NBS studies. Other indications of the success of this activity may be found in the standard fire-resistance test methods and in the studies of the compressive strengths of building materials at elevated temperatures.

In recent years the major emphasis of the program has shifted. Less time is now being spent on determining the fire resistive properties of constructions, and more attention is being given to studying methods for characterizing the important parameters involved in fire protection work. These latter studies have included self-ignition behavior of materials, detection of fires by flame characteristics, methods of measuring surface flammability of materials, mechanisms by which extinguishing agents are effective in fire control, and behavior of materials and constructions as fire barriers.

Self-Ignition of Materials

Ignition characteristics of materials have frequently been reported in terms of an ignition temperature.[2, 3] Such critical temperatures are very elusive. They appear in most cases to depend on the conditions of the experiment and can seldom if ever be considered physical constants of the materials studied. The Bureau is working to obtain a clearer picture of the actual mechanism of slow combustion reactions and the conditions under which they take place. Experience with solids in constant-temperature ovens [4] has revealed the desirability of making measurements in such a manner that specimen size has little if any effect on the experimental results.

An adiabatic furnace [5] has proved useful in analyzing ignition behavior under such conditions. Work to date with this equipment indicates that the slow igni-



Experimental fire being attacked with a vaporizing liquid fire extinguisher. Results of investigations such as these can result in selecting more effective fire extinguishing agents and provide better evaluation of extinguisher performance.

FIRE PROTECTION RESEARCH AT NBS

tion reaction of wood and other cellulosic materials displays the general characteristics of a simple first-order chemical kinetic reaction. This is not strictly the case, however, because there is now evidence that a large number of different reactions are taking place. Nevertheless, it is believed that this method of test provides one of the most useful methods of evaluating the potential storage hazard for bulk materials that may be subject to self-ignition. Eventually it may become possible to develop charts that predict safe storage practices for such materials in terms of material involved, ambient temperature, size of piles of material, and type of ventilation.

Fire Detection in Aircraft Engine Spaces

Recent work in fire detection has been confined to studying the properties of flames likely to occur in aircraft engine spaces.[6, 7, 8] The main problem was to ascertain those properties that can be utilized for fire detection. Particular attention has been directed toward radiant characteristics of such flames. Flicker characteristics were studied and found to occur simultaneously in five spectral bands between 0.23 and 2.5 microns. Results of the work indicate that reliability of the fire detection system can be greatly increased if it is designed to respond only when several intrinsic properties of the flame are all present at the same time. Properties suggested as useful for such purposes include (1) characteristic rate of increase of radiant flux, (2) sufficient level of radiant flux in the required spectral region, and (3) characteristic frequency of flicker.

Surface Flammability

The rate at which fires grow within a building is affected by the type of interior finish used in the construction. Other variables such as combustible content, ventilation, degree of compartmentation, and configuration also seem to be important.

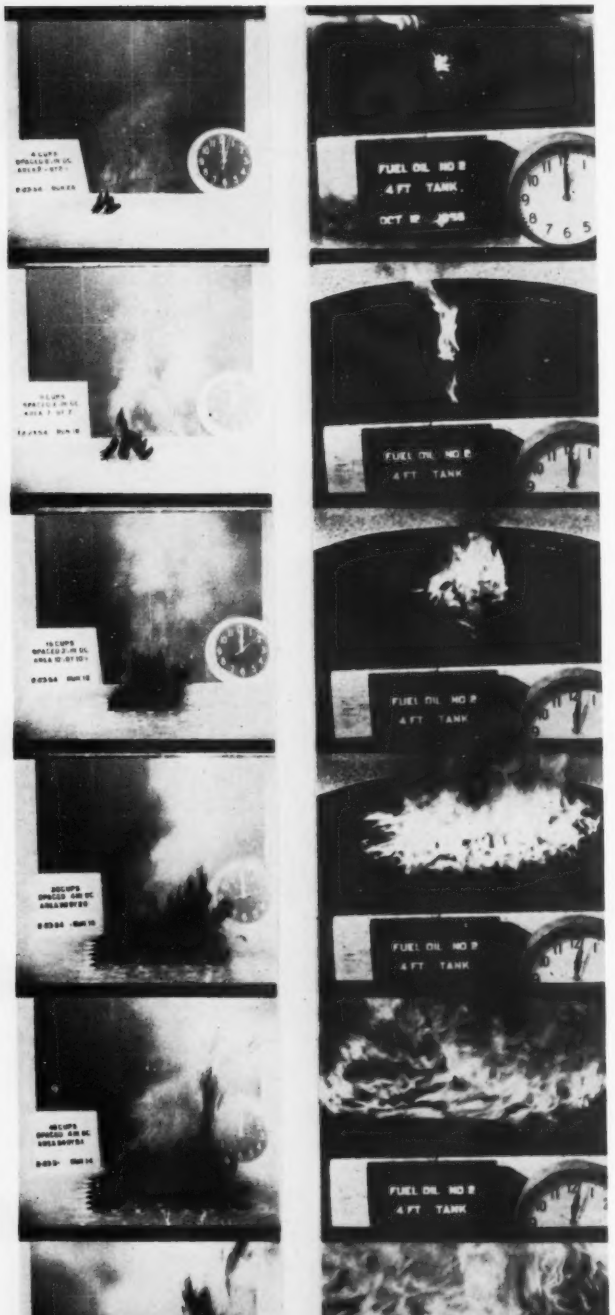
Studies of the rate of growth of fires in buildings are desirable if the hazards to life and property are to be assessed quantitatively. However, the cost and the effort that must be expended on full-scale fires are strong deterrents to such investigations. Immediate attention has therefore been given to developing a laboratory flame spread test method for evaluation of surface flammability of materials.[9]

In this method, ignition is forced at the top of an inclined specimen surface so that combustible gases and flames rise while the flame front on the specimen surface progresses downward. The rate at which the flame moves depends on the characteristics of the material. Both rate of flame travel and rate of heat release (as indicated by exhaust stack thermocouple temperature rise) are observed and their numerical values are combined in an arbitrarily established equation that gives a flame spread index.

The test provides manufacturers and testing laboratories with a reproducible means of studying flammability on a small scale. Acceptance of the flammability ordering achieved by this method as a true indication of fire hazard of the material tested must await full-scale fire growth studies. Other laboratories have elected to use model structures[10] whose behavior has been correlated with a limited number of fire tests of full-size rooms. Although excellent progress has been made in these studies, additional work must be done before real confidence can be placed in the general use of such models.

Methods for Extinguishing Fires

New variations of the "dry chemical" type of fire extinguisher have recently appeared. In most cases the extinguishing agent used is a specially processed



Experimental fires devised to provide a preliminary indication that such fires might serve as models in laboratory investigations. In the series of six negative prints at the left, the number of gasoline-filled cups is increased in each successive experiment to demonstrate interaction of flames from a variable number of small, closely-spaced sources. At right, the progressive spread of fire over the surface of fuel oil is illustrated in six pictures.

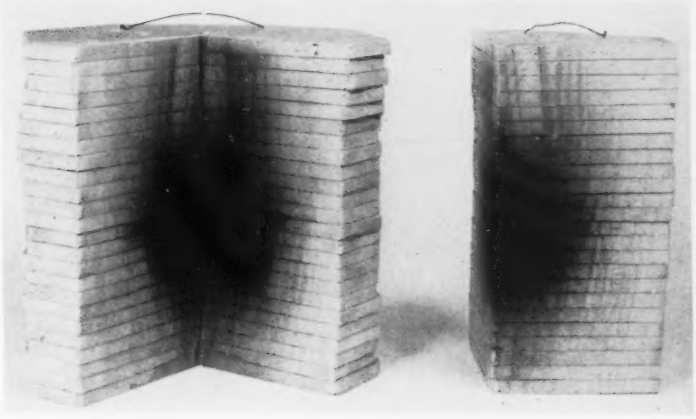
sodium bicarbonate powder. Evaluation of such devices with respect to other types of extinguishers has accentuated the need to understand the mechanism by which they achieve their effectiveness.

For several years the Bureau has been conducting experiments related to the complex problem of fire extinguishment, and considerable progress has been made.[11] The frequently mentioned theory that dry powder extinguishes flammable liquid fires by release of carbon dioxide does not appear to be tenable. Fires have been quickly extinguished by relatively inert powders such as silica. Optical measurements have been made of the effectiveness of dry chemical in shielding the fuel against radiation from the flames. These experiments show that on actual fires the cloud of dry chemical does form an effective radiation barrier, thus reducing the effectiveness of radiation from the flames in vaporizing fuel in a form suitable for combustion. The minimum concentration of the agent necessary for extinguishment has been measured in laboratory experiments.

The results of these studies are expected not only to permit the selection of more effective fire extinguishing agents but also to provide a better understanding of the parameters that should be considered in evaluating extinguisher performance. Although there is definite indication that the radiation shielding effect is important, there is also considerable evidence that some additional mechanism is present in breaking the combustion chemical chain reaction.

Fire Barriers

Studies of the fire resistance of materials and structures have been carried on almost continuously since inception of the fire protection program. Because of the many structural variations and the complexity of analysis of thermal and mechanical behavior, these studies have usually been empirical. A standardized test method determines the fire resistance performance of materials and evaluates it in terms of the exposure time during which the structure maintains stability and prevents excessive heat transfer. The behavior of such simple structures as monolithic concrete slabs during such tests is extremely complex. The presence of water, chemically bound and absorbed, seems desirable in such a structure because the latent heat capacity is very large and may serve to increase the fire endurance. However, in certain types of concrete, large amounts of absorbed water may be harmful. The pressure developed from water vaporizing within specimens has been blamed for severe spalling in several cases.



Fiberboard specimen showing charred central region characteristic of material ignited by self-heating phenomena. Experiments with solids such as these in constant-temperature ovens may give a clearer understanding of the actual mechanism of slow combustible reactions and the conditions under which they take place.

An effort has been made to solve the heat transfer problem in such a slab by numerical approximation techniques. A method was devised for handling the conversion of water to steam within the specimen. The migration of moisture through the specimen was assumed to take place in a variety of ways. It became clear from this work that the number of variables to be arbitrarily selected made it unlikely that a solution based on such assumptions would represent the true behavior. In spite of these difficulties, it still seemed desirable to calculate on SEAC, the Bureau's high-speed electronic digital computer, the temperature distributions that would exist under assumed conditions. It was considered likely that even if the effects of moisture were neglected, solutions for a wide range of specimen sizes might provide a better understanding of the scaling relationships among different-sized specimens of geometrically similar design.

In order to achieve reasonable answers in making these concrete slab computations, it has been necessary to use values of thermal diffusivity that differ by a factor of three from handbook values. For these computations it had been assumed that conduction alone was sufficient to account for heat transfer. However, this is not true; the migration of moisture provides another important transfer mechanism. There is also evidence that radiant heat transfer is an important factor during fire exposure of cellular concretes. Further work should be done on measurement of thermal properties during such transient heating conditions. Problems such as these must be solved in quantitative fashion before real confidence can be placed in theoretical analysis.

Based on a paper presented at the Fire Research Correlation Conference under the auspices of the Committee of Fire Research of the National Academy of Sciences and the National Research Council. To be published by the NAS–NRC, publication No. 475.

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[1] *National Board of Fire Underwriters National Building Code 1955.*

[2] *N. P. Setchkin,* A method and apparatus for determining the ignition characteristics of plastics, *J. Research NBS* **43,** *591 (1949).*

[3] *N. P. Setchkin,* Self ignition of combustible liquids, *J. Research NBS* **53,** *49 (1954).*

[4] *N. D. Mitchell,* New light on self ignition, *Quarterly of the National Fire Protection Association (Oct. 1951).*

Technician is placing specimen in radiant panel flame spread apparatus to test for surface flammability of combustible materials. Ignition will be forced at the top of the specimen so that combustible gases and flames rise while flame front progresses downward. Rate of flame travel and rate of heat release will help establish a flame spread index number for this particular specimen for comparison with indices of other combustible materials.

[5] *W. H. Raskin and A. F. Robertson,* An adiabatic apparatus for the study of self-heating of poorly conducting materials, *Rev. Sci. Inst.* **25,** *541 (1954).*

[6] *W. F. Roeser and C. S. McCamy,* Principles of fire detection in aircraft engine spaces, *WADC Technical Report No. 54-307 (PB-111589), available from U. S. Department of Commerce, Office of Technical Services, Washington 25, D. C.*

[7] *C. S. McCamy,* A five-band recording spectroradiometer, *J. Research NBS* **56,** *293 (1956).*

[8] Fire detection in aircraft engine spaces, *NBS Tech. News Bul.* **41,** *8 (Jan. 1957).*

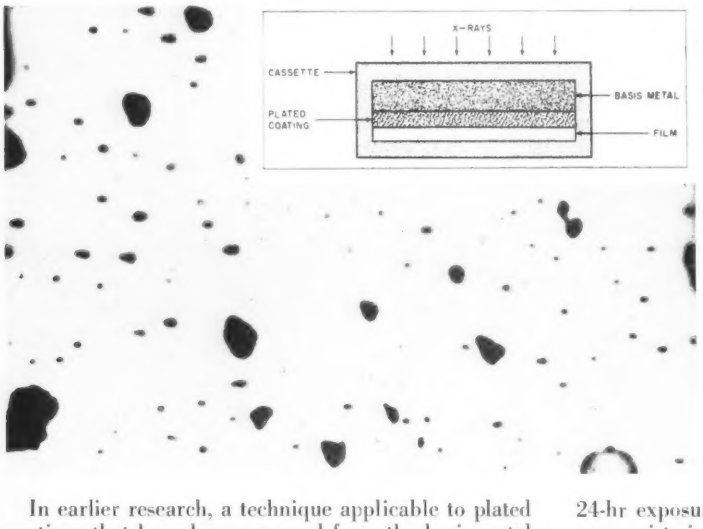
[9] *A. F. Robertson, D. Gross, and J. Loftus,* A method for measuring surface flammability of materials using a radiant energy source, *presented at the 49th meeting of the American Society for Testing Materials, June 17–22 1956. To be published in Proc. ASTM.*

[10] *D. Hird and C. F. Fischl,* Fire hazard of internal linings, *National Building Studies Special Report No. 22 (London 1954, H. M. Stationery Office).*

[11] *C. S. McCamy, H. Shoub, and T. G. Lee,* Fire extinguishment by means of dry powder, *The Sixth International Symposium on Combustion.*

Porosity Detection in Plated Coatings

PORES and other flaws seriously impair the quality of industrially produced electroplated coatings, diminishing their effectiveness as protective coatings for metals. Until now it has been difficult to estimate the relative merits of electrodeposits as no method of determining the gravity of defects was available. Recently, however, a nondestructive procedure has been developed for ascertaining both the size and position of pores.[1] The method involves photographing an electroplated specimen exposed to radiation.



Radiograph of nickel deposit on steel. The large black areas correspond to regions marked as points of reference before plating. Most of the other spots are due to visible gas pits and the smallest dots represent pores. Insert shows the method for investigating the porosity of electroplated coatings. The plated specimen is held against an X-ray film in a cassette with the plated coating against the emulsion of the film. The basis metal side of the assembly is exposed to X-rays or radiations from a radioactive material.

In earlier research, a technique applicable to plated coatings that have been removed from the basis metal was developed by the Bureau.[2] However, the likelihood of stripped-coating porosity differing from adherent-coating porosity led to further investigation of the problem. The present work was carried out for the American Electroplaters' Society by F. Ogburn of the Bureau staff and Margaret Hilkert of the Society's research fellowship at the Bureau.

In determining the location and size of pores, the specimen, a flat sheet of plated metal a few thousandths of an inch thick, is placed on a photographic film with the coating against the film emulsion. The assembly is held in a cardboard cassette, and the basis-metal side of the specimen is exposed to X-rays or radiation from a radioactive material. To insure good contrast, the X-radiation used must be soft. This requirement of low-energy X-rays limits the thickness of the basis material to several thousandths of an inch, because thicker metal absorbs too much of the X-ray beam and requires too long an exposure time. Radioactive iron, nickel, or cobalt held against the plated specimen in a cassette are also adequate sources of radiation.

After a suitable exposure time the film is removed and developed. Satisfactory radiographs result from a 3- or 4-min exposure to an X-ray machine, and from a 24-hr exposure to 1 μC of radioactivity. Wherever a pore exists in the coating, a black spot appears on the developed film. A fine-grain industrial X-ray film gives the most readable radiograph.

This radiographic method detects pits, voids, and inclusions in the coating to the order of 0.001 in. in diameter. Discontinuities in the basis metal may also be determined by radiographing the metal before plating.

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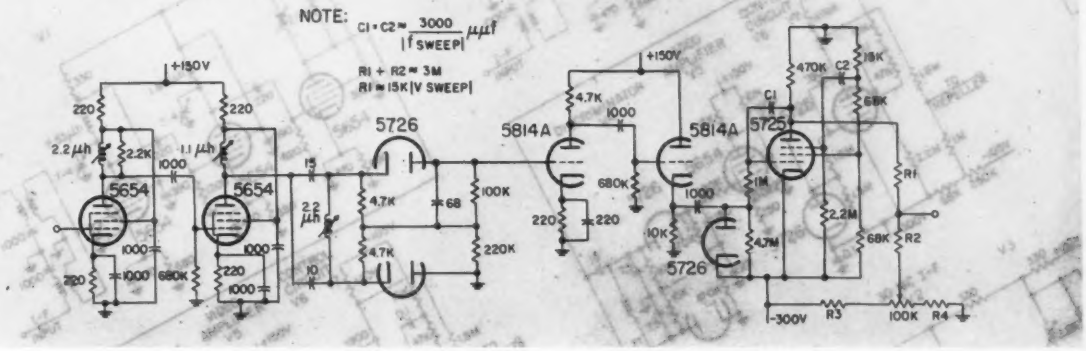
[1] The nature, cause and effect of porosity in electrodeposits, II. Radiographic detection of porosity in electrodeposits, *by F. Ogburn and M. Hilkert, Annual Tech. Proc. Amer. Electroplaters' Soc., p. 256 (1956).*

[2] The nature, cause, and effect of the porosity in electrodeposits, *by F. Ogburn and A. Benderly, Plating* **41,** *168 (1954).*

Preferred AFC Circuit



AS PART OF A PROGRAM to minimize design effort, increase reliability, and reduce production costs of military electronic equipment, the Bureau has derived an automatic frequency control (afc) circuit. This preferred circuit is a practical solution to a frequently recurring circuit design problem, and is applicable wherever a 30-Mc intermediate frequency is used with pulse widths between 0.5 and 5.0 μsec. Produced for the Navy Bureau of Aeronautics by G. Rogers of the NBS engineering electronics laboratory, the circuit will be incorporated into a forthcoming supplement to the Handbook of Preferred Circuits [1] published jointly by the Navy and NBS.

The Bureau has found that it is feasible to standardize many of the well-known electronic circuits that are common to a wide variety of aeronautical equipment. Various versions of the same kind of circuit found in different devices differ only in minor details. This has been observed to be true in the case of rectifiers, regulators, amplifiers, detectors, pulse generators, etc. By standardizing many of these basic electronic building blocks, worthwhile advantages to the military user and to the industrial producer can result through greater operating reliability, fewer spare parts for maintenance, and economies in design and production engineering. One of the building blocks recently investigated is an automatic frequency control that illustrates the type of circuit where the standardization approach is possible.

In a typical radar system, the automatic frequency control circuit maintains a constant frequency difference between the transmitter and local oscillator signals by feeding a portion of the transmitter signal along with the local oscillator signal to the afc mixer. The difference frequency produced by the mixer develops an error signal whose magnitude and sense are proportional to the amount and the direction by which the difference frequency departs from the desired intermediate frequency. The error signal is amplified and then corrects the frequency of the local oscillator. An additional requirement in most microwave systems is that the local oscillator search for the correct difference frequency when the equipment is turned on, when the transmitter signal is interrupted, or when the transmitter signal suddenly shifts beyond the "hold-in" range of the afc.

The portion of the afc system between the mixer and the local oscillator is usually a self-contained subassembly and is a logical choice for a preferred circuit. A preliminary study of a number of existing circuits revealed that they are composed of a few basic types. The mixer is followed by IF amplifiers which are usually synchronously tuned; the number of stages varies with the bandwidth requirements. In the majority of cases, Weiss discriminators are used to develop the error signal in preference to the Foster-Seeley circuit. The video amplifiers, used as error amplifiers, vary from single triodes and pentodes to pentode-triode and pentode cathode-follower combinations. The control circuits, which also function as sweep generators, are either of the thyratron or phantastron types with the trend toward the latter.

The performance requirements of these circuits fall within fairly narrow limits. The bandwidth of the IF amplifier and the peak separation of the discriminator are determined by the pulse width of the transmitted signal. Because many radar systems employ both short and long pulses, it was essential to accommodate the range of pulse widths without adjustment. Two IF amplifier stages were required to obtain the necessary gain and bandwidth. Although the input signal is constant for a particular system, it varies from 50 to 500 mv among the systems studied, and it is necessary to adjust the gain to suit the input level because of the possibility of responding to crystal harmonics. The gain is adjusted by varying the plate load resistors in the IF and video amplifiers. This is permissible in the former case because the bandwidth requirements are not rigidly fixed.

The diode-phantastron control was selected instead of the thyratron for the preferred circuit because of its better performance. The sweep rate can be adjusted by selection of the two feedback capacitors, the sweep amplitude by the divider on the output of the phantastron, and the sweep centering by the "Range Set" divider.

The choice of input circuit is properly a part of the mixer design. The IF amplifier and discriminator are designed for the shortest pulse, and no adjusting controls are provided—or required—for bandwidth. The preferred afc circuit will operate at pulse widths between 0.5 and 5 μsec and duty factors between 0.001 and 0.0001. It can be adjusted for input signal levels between 50 and 500 mv. The sweep output is a sawtooth that can be adjusted for rates between 0.1 and 10 cps, amplitures between 40 and 150 v, and averaged d-c levels between 0 and —200 v. The values for the eight components necessary to make these adjustments are specified in terms of performance requirements. The result is a circuit that is usable, without sacrifice in performance, in most afc systems operating in pulse systems with 30 Mc IF's.

For further general information on this program, see NBS-BuAer preferred circuits program, *NBS Tech. News Bul.* **38,** *134 (Oct. 1955).*

[1] Handbook Preferred Circuits Navy Aeronautical Equipment NAVAER 16-1-519. *Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price, $1.75.*

Fatigue Failure of Long Springs

MANY MECHANICAL DEVICES use long helical springs under compressive loads; such springs require a guide rod or tube to prevent buckling. A recent study by C. L. Staugaitis and H. C. Burnett [1] of NBS has shown that the action of the guide rod causes a marked reduction in the life of the springs under fluctuating loads. The study was made in connection with a research program on the fatigue properties of music wire and springs that the Army Ordnance Corps has been sponsoring at the Bureau.

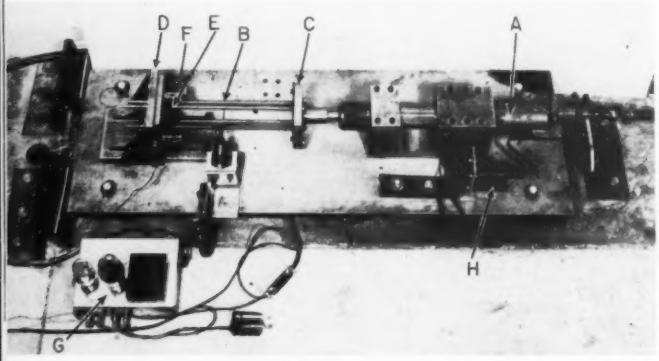
Metals subjected to fluctuating loads may fail at stress levels much lower than that which they can support safely under steady conditions. This phenomenon, known as fatigue, is of major importance in mechanisms, such as machine guns, in which the springs and other parts must withstand many cycles of high stress. Previous work on this project has been devoted principally to studying the properties of music spring wire and short springs,[2] that is, springs of such a shape that they can be compressed without buckling.

To investigate the effect of the guide rod required in long springs, a pneumatically operated machine was constructed which is capable of stressing as many as four long springs at a frequency of about 10 cycles per second.

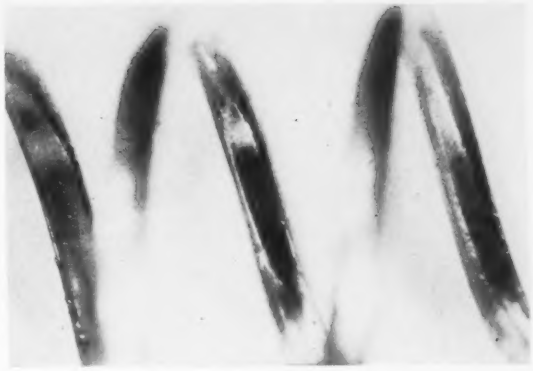
The springs were made from samples of 0.39-in. diameter music wire which had been obtained from two different sources of supply. They were carefully coiled at a predetermined pitch and coil diameter, so that the clearance between the guide rod and the inside of the spring was approximately 4 percent of the inside diameter of the spring.

In a helical extension or compression spring, the wire is loaded in torsion. Consequently, the maximum tensile stress occurs in a direction at 45° to the length of the wire, whereas the directions of maximum shearing stress are parallel and perpendicular to the length.

In springs tested at relatively high stress ranges, the initial fatigue cracks developed (because of the shearing stress) on longitudinal planes. These cracks frequently propagated along a considerable length of the wire, causing a marked loss of stiffness before fracture and under certain conditions making it impossible to fracture the springs. To determine some criterion of failure that would indicate the useful life of the springs, tests on two springs were interrupted at regular intervals to measure the spring properties. From the data thus obtained, it was decided that the first collapse of a coil under load could be considered as the point of failure.



Fatigue machine for studying the behavior of long helical springs under fluctuating loads. As many as four springs can be tested simultaneously at a stress range determined by the design of the springs. A pneumatic cylinder and piston (A) constitute the driving mechanism. Specimens (B) are mounted on guide rods threaded into the movable collar plate (C), which is attached to the piston shaft. The springs are compressed between C and the fixed plate (D), which contains openings for the guide rods. Hardened steel washers (E) support the ends of the springs adjacent to the fixed plate. If the test spring breaks or suffers a predetermined loss in free height, a light compression spring behind the washer pushes the washer into contact with an adjustable stop (F). When this contact is made, an electronic relay (G), in conjunction with a solenoid-operated air valve (H), stops the machine.



Portion of a long spring showing marked degree of guide-rod wear on inside surfaces. Studies have shown that this wear greatly reduces the fatigue life of long springs under fluctuating compressive loads. The middle coil of the spring also contains a fatigue crack running parallel to the wire. (× 15)

Application of this criterion showed that the fatigue life of long springs is considerably shorter than that of short springs[2] at corresponding levels of stress. Examination of the long springs that were tested indicated that an important cause of the lower fatigue life was the wear on the inside of the spring, where contact was made with the guide rod. All of the spring failures occurred in the first third of the spring length adjacent to the fixed head, where the rubbing action of the guide rod was at a maximum.

There are two reasons why wear could cause a reduction in fatigue strength. First, the loss of material reduces the polar moment of inertia of the cross section so that the applied load causes a higher stress. Second, the rubbing action can result in galling or fretting of the surface, with consequent formation of pits that can serve as nuclei for fatigue cracks.

To determine the effect of lubrication on the fatigue life of long springs, a series of additional tests was carried out in which lubricant was applied to the guide rods and springs. Comparison of the results thus obtained with the data for the unlubricated springs indicates that lubrication with dry molybdenum disulfide may more than double the fatigue life of the springs for stress levels below 150,000 psi. At the higher levels of stress little improvement was noted.

[1] *For further technical details, see* The behavior of long helical springs under fluctuating load, *by C. L. Staugaitis and H. C. Burnett, Proc. Am. Soc. Testing Materials* **55,** *918 (1955).*

[2] Endurance of helical springs related to properties of the wire, *by H. C. Burnett and C. L. Staugaitis, Metal Progr.* **64,** *77 (Sept. 1953).*

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March 1957 **Issued Monthly** **Vol. 41, No. 3**

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price, domestic $1.00 a year; 35 cents additional for foreign mailing; single copy, 10 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (March 29, 1956).

Contents

	Page
Weathering of porcelain enamels	33
Small oil-free bearings	35
Punched-card transcriber for automatic computers	38
URSI to meet in Boulder	39
Fire protection research at NBS	41
Porosity detection in plated coatings	44
Preferred automatic frequency control circuit	45
Fatigue failure of long springs	46
Publications of the National Bureau of Standards	47

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Plastics. Gordon M. Kline. J. Eng. Mech. Div. Am. Soc. Civil Engrs. (American Society of Civil Engineers, 33 W. 39th St., New York 18, N. Y.) **82,** No. EM4, (October 1956).

Sources of error in various methods of airplane camera calibration. Francis E. Washer. Photogrammetric Eng. (1515 Massachusetts Avenue, N. W., Washington 5, D. C.) **22,** No. 4, 727–740 (September, 1956).

Spin-spin absorption in chromic methylammonium alum and manganous chloride tetrahydrate at very low temperatures. E. Ambler and R. P. Hudson. Physica. (Treas. Physica Foundation, Bijlhouwerstr. 6, Utrecht, Neth.) **22,** 866–868 (1956).

Contributions to the theory of rank order statistics—the two-sample case. I. Richard Savage. Annals Math. Statistics. (Waverly Press Inc., Baltimore, Maryland) **27,** No. 3, (September, 1956).

Excitation and separation of pure high-order modes in large high-Q cavities. C. T. Zahn and W. G. Schweitzer, Jr. J. Appl. Phys. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **27,** No. 8, 929–937 (Aug. 1956).

Gravitational and thermal oscillations in the earth's upper atmosphere. M. L. White. J. Geophys. Research. (The Johns Hopkins Press, Baltimore 18, Maryland) **61,** 489–499 (Sept. 1956).

Infrared spectra of hydrogen cyanide and deuterium cyanide. Harry C. Allen Jr., Eugene D. Tidwell, and Earle K. Plyler. J. Chem. Phys. (American Inst. of Physics, Inc., 57 E. 55th St., New York 22, N. Y.) **25,** No. 2, 302–307 (Aug. 1956).

Measurements on sound absorbers for jet-engine test cells. Richard V. Waterhouse, Richard K. Cook, and Raymond D. Berendt. J. Acoust. Soc. Amer. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **28,** No. 4, 688–692 (July, 1956).

The infrared spectrum of acetylene-d_2. Harry C. Allen, Jr., Eugene D. Tidwell, and Earle K. Plyler. J. Am. Chem. Soc. (American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.) **78,** 3034 (1956).

Stress corrosion cracking of type 304 austenitic stainless steel. H. L. Logan, and R. J. Sherman, Jr. Welding J., Research Suppl. (Am. Welding Society, 33 West 39th St., New York 18, N. Y.) **35,** No. 8, 389s (August, 1956).

Thermal degradation of unvulcanized and vulcanized rubber in a vacuum. Sidney Straus and S. L. Madorsky. Ind. Eng. Chem. (American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.) **48,** 1212 (July, 1956).

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Patents

(The following U. S. Patents have been granted to NBS inventors. Assigned to the United States of America, as represented by the Secretary of the Department noted in parentheses.)

No. 2,765,270. October 2, 1956. Alkali titanium halide compositions. Abner Brenner and Joseph M. Sherfey. (Commerce).

No. 2,764,914. October 2, 1956. Apparatus for cooling gun barrels. John P. Young. (Commerce).

No. 2,766,134. October 9, 1956. Method for restoring original appearance of impregnated leather by dissolving the impregnant on the surface of the leather. John H. Davis. (Commerce).

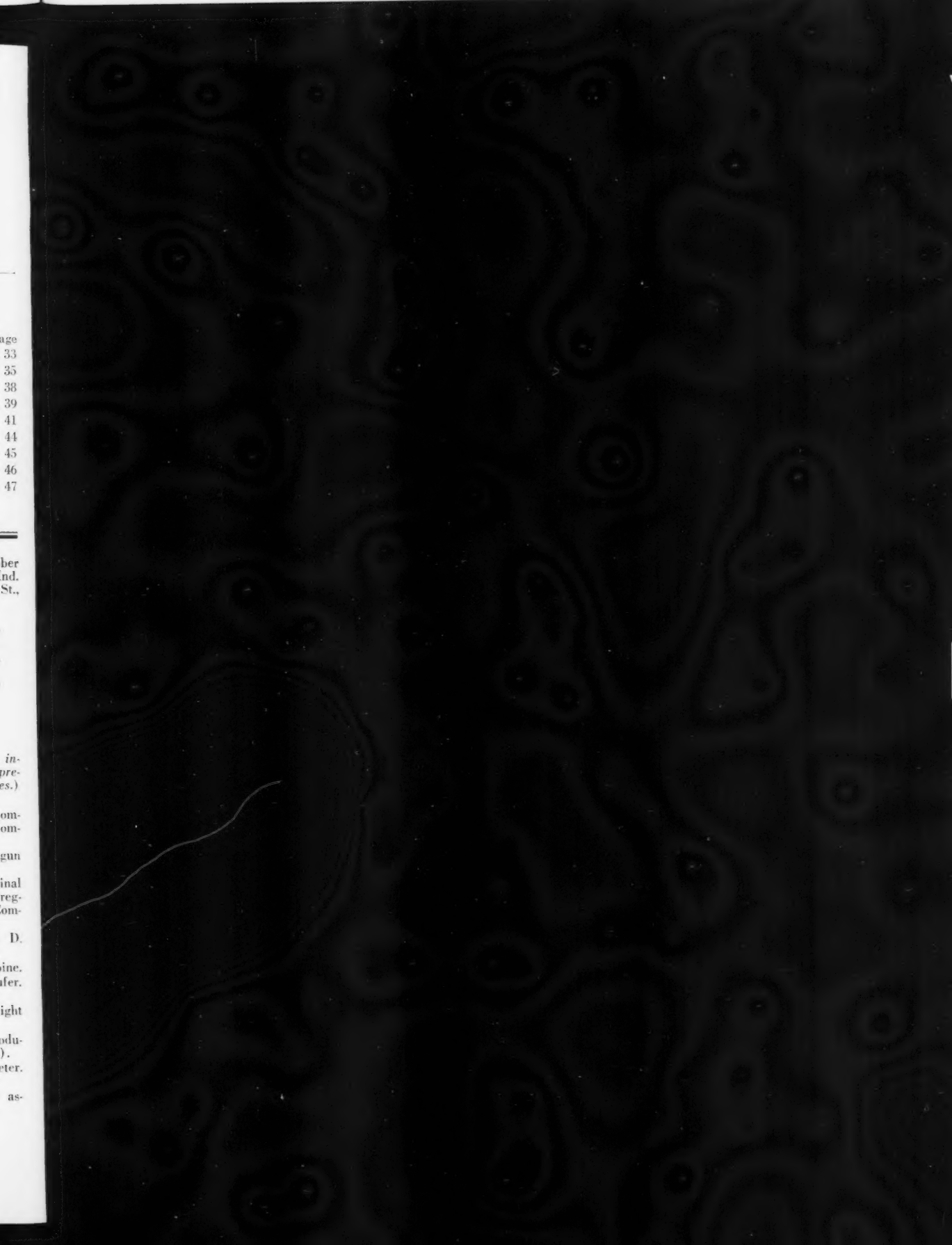
No. 2,766,618. October 16, 1956. Tire tester. Robert D. Stiehler and Andrew P. Gregg. (Commerce).

No. 2,766,964. October 16, 1956. Self-governing turbine. Nils T. Almquist, Myron G. Domsitz, and Max Shufer. (Army).

No. 2,769,164. October 30, 1956. Multichannel pulse-height analyzer. James A. Cunningham. (Commerce).

No. 2,771,663. November 27, 1956. Method of making modular electronic assemblies. Robert L. Henry, Jr. (Navy).

No. 2,772,597. December 4, 1956. Precision refractometer. Oscar H. Grauer. (Commerce).

No. 2,774,014. December 11, 1956. Modular electronic assembly. Robert L. Henry, Jr. (Navy).

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